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FACTORS DETERMINING THE QUALITY OF DECORATIVE PLASMA COATINGS ON GLASS

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The results of studying reactions of glass particles deposited by plasma spraying with a glass substrate are described. It is shown that the main factors determining the quality of a decorative coating on a glass article are the operating parameters of the plasma gun and the temperature of preheating of the substrate.

Decorating glass and glass articles by the plasma-spraying method is a promising direction in the development of new types of decorative coatings [1]. The plasma technology for depositing decorative vitreous coatings has several advantages compared with the traditional methods. The main advantages include the elimination of the time- and energy-consuming firing process needed to fix the decorative coating on an article, as well as the possibility of using a decorating material whose T_g exceeds the T_g of the substrate [2].

The present paper describes the results of a study of reactions between the deposited glass particles and the glass substrate, as well as the effect of the technological parameters on the strength of adhesion between the decorative coating and the substrate.

The initial materials were sheet glass and glass tableware (tall and small wine glasses, liqueur glasses, etc.) made of lead crystal glass, chromium-tinted green glass, selenium ruby glass, and black and blue marblite [2]. The above glass was crushed, and the cullet was used to make rods of diameter 0.8 – 2.2 mm and 350 – 450 mm long, using the spray deposition and drawing methods. Next, the rods were deposited on glass articles by plasma spraying, employing a GN-5p burner on a UPU-8M plasma gun. The operating parameters of the plasma gun and the temperature of preheating of the substrate varied in the course of the experiment.

After plasma spray deposition of decorative coatings, the strength of adhesion of the coating to the substrate was determined by the following method. The thickness of an individual deformed deposited drop was measured by a micrometer, and its diameter was measured using a microscope. Next, the substrate surface was covered by paraffin, and the surface of the deposited drop was cleaned and pickled in fluoric acid for 20 sec with subsequent washing in water. After drying, a steel rod was glued to the treated surface of the deposited particle with epoxy resin. By uniform loading of the rod, the critical load, under which the particle broke away from the substrate, was determined. The testing was carried out on an R-5 tensile-testing machine. [3]

The process of plasma spray deposition of decorating glass on a glass substrate occurs in several consecutive or simultaneous stages: the introduction of the decorating material in the plasma burner, the heating and melting of the material, the dispersion and migration of particles in the flow of plasma-forming gas, coagulation (or crushing) of particles in the gas flow, their spheroidizing, the impact of particles on the surface of the decorated glass article, and the formation of a decorative coating.

The operating parameters of the plasma gun and the temperature of preheating of the coated articles can be regarded as the factors forming the quality of the decorative coating. The type of reaction of deposited particles with the substrate also affects the qualitative parameters of the coating. The melted glass particles hitting the substrate become soldered to it and deformed to a different degree, depending on the flow rate of the plasma-forming gas and the work power of the plasma gun. Thus, with a plasma gun power of less than 7.5 kW and a rate of the plasma-forming gas of 0.00093 g/sec, the glass particles hitting the substrate get insignificantly deformed (Table 1). This is due to the fact that the glass particles do not have time to get heated to high temperatures and, accordingly, have high viscosity. As a result of this, the dynamic thrust of the plasma jet is insufficient to ensure substantial deformation of the particles and their soldering to the substrate.

As the strength of the current in the plasma gun increases to 350 – 400 A, and the plasma-forming-gas rate increases to 0.00114 g/sec, the plasma temperature grows and, accordingly, the heating temperature of the decorating material becomes higher. As a consequence, the speed of sprayed particles increases and their viscosity decreases. A melted particle softens the surface layer of the substrate at the point of con-

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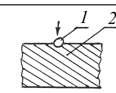
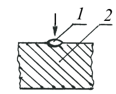
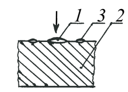
TABLE 1

Plasma gun operating parameters		Flow rate of plasma-forming gas, g/sec	Degree of deformation of sprayed particles	Strength of adhesion to substrate, MPa, with coating thickness 200 μm and substrate preheating to temperature, K			Scheme of particles hitting substrate*
strength of current, A	work voltage, V			298	523	723	
200	30	0.00093	Insignificant	–	–	–	
225	30	0.00093	The same	0.9	1.3	2.5	
250	30	0.00093	″	–	–	–	
300	30	0.00114	Medium	–	–	–	
350	30	0.00114	The same	5.4	7.8	10.3	
400	30	0.00114	″	–	–	–	
425	30	0.00163	Intense with formation of break-away drops	–	–	–	
450	30	0.00163		6.8	8.2	12.4	
500	30	0.00163		–	–	–	

* *1*) sprayed particles; *2*) substrate; *3*) break-away drops.

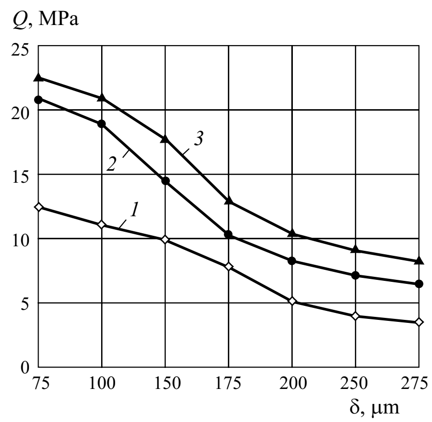


Fig. 1. Dependence of the strength of adhesion Q of a coating to a substrate on the sprayed layer thickness δ with substrate temperatures of 298 (*1*), 523 (*2*), and 723 K (*3*) (operating parameters of plasma gun: current 350 A, voltage 30 V, gas rate 0.00114 g/sec).

tact and itself becomes significantly deformed. The strength of adhesion of such a coating to the substrate is significantly higher than in weakly deformed particles (Table 1).

As the power of the plasma gun grows to 15 kW and the flow rate of the plasma-forming gas increases to 0.00163 g/sec, the particles in the plasma torch get heated to temperatures significantly exceeding T_f of the glass and, accordingly, have relatively low viscosity. As a consequence of this fact, the particles, at the moment of hitting the substrate, become significantly deformed, and break-away drops are formed. The latter have low strength of adhesion to the substrate.

The following parameters of the plasma gun can be regarded as the optimal ones: work voltage 30 V; current 350 A; flow rate of the plasma-forming gas 0.00114 g/sec.

It is known that as the substrate preheating temperature grows, the strength of adhesion of the coating to the base increases [4]. Thus, the experiments demonstrated that when glass articles are preheated, the strength of adhesion registered under the fixed optimum parameters of the plasma gun is on the average 1.5 – 2 times higher than in articles without preheating.

The thickness of the deposited layer also has a substantial effect on the adhesion strength. As the thickness of the decorative coating increases, the strength of adhesion to the substrate decreases. This is due to the scale factor and the value of residual stresses accumulated in the coating [5]. As the thickness grows from 80 to 280 μm, the strength of adhesion of the decorative coating to the substrate in articles without preheating decreases, respectively, from 12.5 to 3.5 MPa. Preheating of glass articles to 723 K before spray deposition contributes to a substantial increase in the strength of adhesion of a decorative coating to the substrate (Fig. 1). Accordingly, the preheating of a substrate is one of the main factors that determines the quality of a decorative coating, in particular, its functional properties, including the service life of the decorative layer on the article.

Thus, the study established the effect of the main factors on the properties of decorative plasma coatings.

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